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GENERALIZATION OF A TACTILE STIMULUS IN HORSES

DONALD M. DOUGHERTY AND PAUL LEWIS

UNIVERSITY OF TEXAS HEALTH SCIENCE CENTER AND OHIO UNIVERSITY

Using horses, we investigated the control of operant behavior by a tactile stimulus (the training stimulus) and the generalization of behavior to six other similar test stimuli. In a stall, the experimenters mounted a response panel in the doorway. Located on this panel were a response lever and a grain dispenser. The experimenters secured a tactile-stimulus belt to the horse's back. The stimulus belt was constructed by mounting seven solenoids along a piece of burlap in a manner that allowed each to provide the delivery of a tactile stimulus, a repetitive light tapping, at different locations (spaced 10.0 cm apart) along the horse's back. Two preliminary steps were necessary before generalization testing: training a measurable response (lip pressing) and training on several reinforcement schedules in the presence of a training stimulus (tapping by one of the solenoids). We then gave each horse two generalization test sessions. Results indicated that the horses' behavior was effectively controlled by the training stimulus. Horses made the greatest number of responses to the training stimulus, and the tendency to respond to the other test stimuli diminished as the stimuli became farther away from the training stimulus. These findings are discussed in the context of behavioral principles and their relevance to the training of horses.

Key words: stimulus generalization, tactile stimulus, lip press, horse

Considerable experimental evidence demonstrating the effectiveness of tactile stimuli in controlling classically conditioned behavior was gathered during the early 1900s. One of the scientists responsible for collecting this evidence was G. V. Anrep, who spent many years investigating classically conditioned responses in Pavlov's laboratory at the Institute of Experimental Medicine in Petrograd. Several different types of stimuli, including "pressure by smooth and rough surfaces, pressure by blunt points arranged in various patterns, and . . . scratchings in various directions with a small brush," were used (Pavlov, 1927/1960, p. 137). Using the dog's salivary reflex, Anrep showed that a previously neutral tactile stimulus, the conditioned stimulus (CS), paired repeatedly with another stimulus, the unconditioned stimulus (UCS), that normally elicited the salivary response came to elicit the same response. He also demonstrated that after a conditioned stimulus had been established, other novel tactile stimuli would also elicit a salivary response. For example, in one experiment (Pavlov, p. 185) an apparatus was used that could deliver a tactile stimulus to six specific places on the dog's body: the hind paw, the pelvis, the middle of the trunk, the shoulder, the foreleg, and the front paw. After first establishing the tactile stimulus given to the dog's thigh as a conditioned stimulus by pairing it with the unconditioned stimulus (food powder delivered to the dog's mouth), Anrep presented the other five stimuli individually and measured the amount of saliva elicited during a 30-s period following delivery. He found that these novel stimuli also elicited a salivary response, but to a lesser degree depending on the location of the novel stimulus. Stimuli that were in close proximity to the thigh (at the hind paw and the pelvis) elicited more saliva than did stimuli that were farther away from the conditioned stimulus (the foreleg and the front paw).

Some criticisms (see Loucks, 1933) and controversies surrounding Anrep's "clearly positive findings" (Bass & Hull, 1934, p. 47) and Pavlov's research laboratory led Bass and Hull to conduct a similar classical conditioning experiment with humans. They too used tactile stimuli, but they paired the stimuli with shock to condition a galvanic skin response. To do

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this, Bass and Hull positioned their subjects on an army cot with a blanket suspended above the lower portion of their body and a box-like structure suspended over their upper bodies to shield light. Tactile vibratory stimulators were placed at four locations along the left side of the subject's body (shoulder, back, thigh, and calf). The conditioning trials involved the delivery of a tactile stimulus (CS) immediately followed by shock (UCS) to condition a galvanic skin response, naturally elicited by shock. Following conditioning trials, several extinction trials were given, in which each of the tactile stimuli was delivered alone and the magnitude of the subject's galvanic skin response was measured. In extinction, galvanic skin responses were not only elicited by the CS but were also elicited by the other novel tactile stimuli. The strength of the elicited response was, however, dependent on the stimulus's relative proximity to the CS. Galvanic skin responses were larger when the stimulus was located near the CS than when they were located farther away from the CS. These results supported Anrep's findings and expanded this phenomenon to include another species and another response.

Many years after these two demonstrations of the generalization of classically conditioned responses, Guttman and Kalish (1956) studied the generalization of operantly conditioned responses. In their experiment, several pigeons were first trained to peck at a key that was illuminated from behind with a narrow band of wavelengths of light (the training stimulus). After pigeons had acquired the key-peck response, their responses were maintained (in the presence of the training stimulus) for several days on intermittent-reinforcement schedules. This was immediately followed by a generalization test in which novel stimuli were presented. Pigeons were presented with 11 different wavelengths of light. Each wavelength was randomly presented several times for 30 s, and the number of responses to each wavelength were counted. Like Anrep, Guttman and Kalish found that pigeons emitted the greatest number of responses in the presence of the training stimulus and fewer in the presence of the other stimuli. Furthermore, the pigeons' tendencies to respond to each of these novel stimuli weakened as the wavelengths became farther away from that of the training stimulus. (For a review of stimulus-generalization experiments, see Honig & Urcuioli, 1981.)

The phenomenon of generalization and the use of tactile stimuli have some practical applications to the control of horse behavior, because horses are often controlled by riders through the delivery of subtle tactile stimuli (often called aids by riders). These stimuli are most often given in one of three ways to the horse: to the horse's mouth with the bit, to the sides of the horse's belly with the rider's legs, or to the horse's back with the rider's posture or position in the saddle. In spite of the widespread use of tactile stimuli to control behavior of horses, researchers have not investigated them experimentally. In the present experiment, we investigated the control of operant behavior by a tactile stimulus and determined the generalization of control to other similar tactile stimuli. To do this we constructed an apparatus that delivered tactile stimuli at seven locations along the horse's back. In addition, several other aspects of the present experiment were of interest; these included the training of the lip-press responses, the rates of responding on intermittent-reinforcement schedules, and the overall adaptability of the horse to the experimental procedures.

METHOD

Subjects

Three horses, 2 of predominantly Arabian breeding and 1 registered quarter horse, served as subjects. The Arabians, Chris and Kay, were mares weighing approximately 367 kg and 384 kg, respectively; the quarter horse, No Sweat, was a gelding weighing approximately 462 kg. We estimated weights from girth measurements. The horses' ages varied: Chris was 6, Kay was 16, and No Sweat was 7 years old.

Apparatus

A barn stall (3.5 m in length, 3.4 m in width, and 2.7 m in height) served as a testing chamber. The walls were wood, and the floor was dirt. Along the front wall of the stall were a large window with bars and a doorway. The daylight that came through the barred window in front, a small window on the back wall, and a skylight in the ceiling provided illumination in the stall.

In Figure 1, the two major parts of the ex-

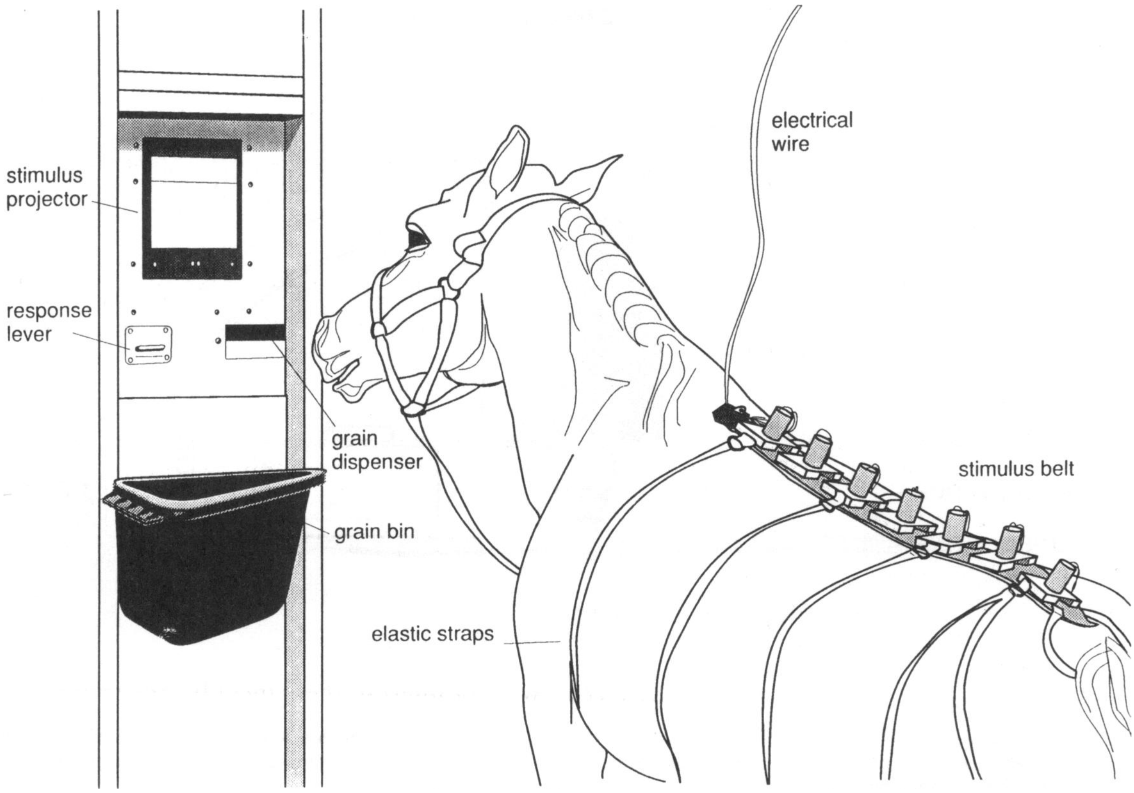

Fig. 1. A diagram of the two major components of the experimental apparatus: the stimulus belt placed on the horse's back and the response panel mounted in the stall's doorway.

perimental apparatus are shown: (a) the response panel that was positioned in the stall's doorway and (b) the stimulus belt that was placed on the horse's back. The response panel was constructed by making a wooden frame (127.0 cm in height and 43.2 cm in width) and mounting a rectangular piece of thin aluminum sheet metal (63.2 cm in height by 43.2 cm in width) on this frame 69.4 cm above the floor. This panel contained a response lever, a grain dispenser, and a stimulus projector (not used in this experiment). On the bottom left side of the panel, we mounted (centered 47.5 cm from the top and 12.7 cm from the left side of the metal panel) a Gerbrands rat lever (Model G6312). The lever itself was 5.1 cm wide, 1.3 cm thick, and protruded 17.5 mm from the lever's housing; a minimum force of 0.40 N was required to operate it. On the bottom right side of the panel, we made an opening (12.7 cm by 6.4 cm) for the grain dispenser (centered 61.0 cm from the top and 12.7 cm from the right side of the panel). The grain dispenser mechanism itself, mounted on the back of the panel, consisted of a grain chute (27.9 cm long) with a hinged flap (at the top of the chute) that could hold and release a charge of grain. A 110-V solenoid held this flap, which, when released, allowed the grain to fall through the chute into a large feed bin positioned 24.0 cm below the feeder opening. The stimulus belt, made of a burlap fabric strip 91.1 cm long and 9.0 cm wide, weighed 1.1 kg. On the burlap we mounted seven cylindrical solenoids (12 VDC Shultz 0.17 A), each positioned 10.0 cm apart from center to center. When one of these solenoids was operated, a 12.3-g piston (9.5 mm in diameter by 2.7 cm in length) was drawn up into the solenoid's housing and released at a rate of four times per second, resulting in a light tapping stimulus. Directly under each piston, we cut a small square hole and sewed a light piece of cotton fabric flush to the underside of the burlap; this allowed the solenoid's piston to stimulate the horse's skin. The construction of

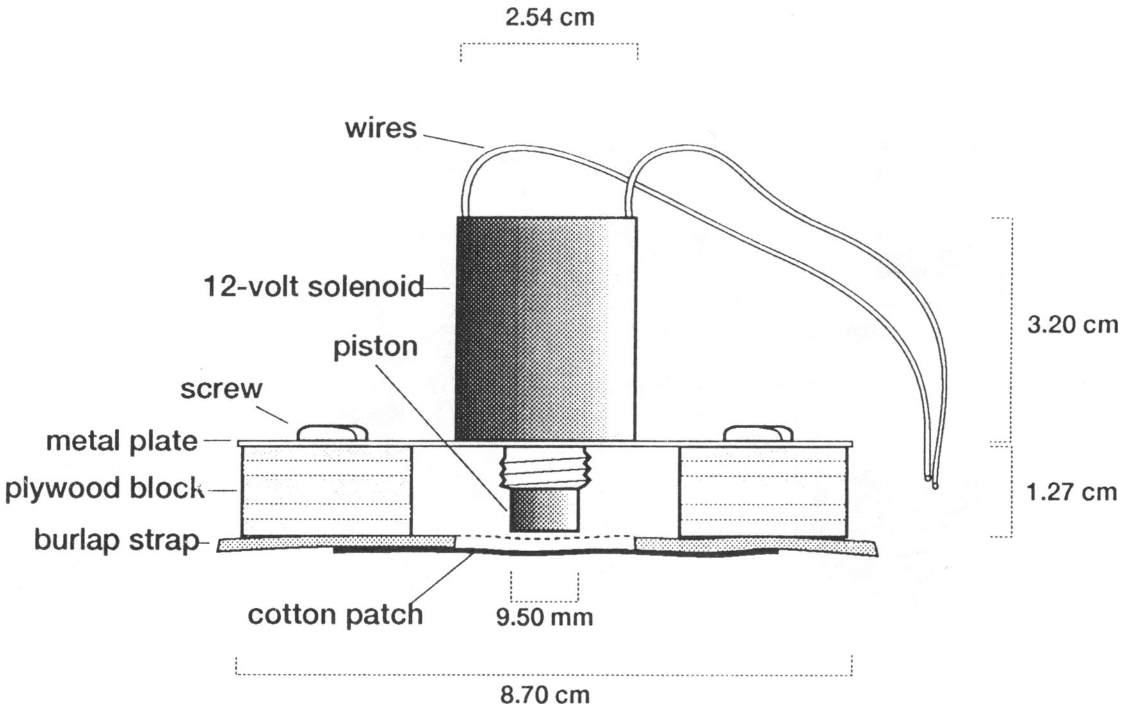

Fig. 2. A diagram of one of the individual tactile devices showing its construction and dimensions. Each of these devices was capable of delivering a tapping stimulus to the horse's back. When operated, the solenoid's piston was drawn up into its housing and released at a rate of four times per second.

one of these tactile devices is illustrated in Figure 2. The wiring needed to control each of these solenoids was sewn along the edges of the belt to the front, nearest the horse's head, where a cable socket was attached. During sessions, this socket was attached to an electrical cable that hung from the ceiling.

The other end of the electrical cable went to a control box that, in turn, allowed the experimenters to control and monitor the stimulus belt, the response lever, and the grain dispenser from outside the horse's stall (and outside the horse's view). A 12-V deep-cycle battery was used to power the control box as well as a 110-V power inverter; the 110-V power controlled the food dispenser's solenoid. This system allowed the experimenters to record the number of lever presses made, turn on each of the stimuli for a designated period of time, and to arm the grain dispenser manually so that a charge of grain would be delivered automatically with the next response.

Procedure

Early each afternoon, all 3 horses were taken from a large pasture and led to the barn for testing. While 1 horse was being tested, the other 2 remained in adjacent holding paddocks. Horses were tested individually in the same order every day: Chris first, Kay second, and No Sweat third. (Chris, who had recently given birth, was tested with her foal at her side.) The horse being tested was first led into the testing stall and tied in a corner so that the stimulus belt could be attached. Four elastic straps around the horse's midsection, and another around the base of the horse's tail, held the stimulus belt firmly in position on the horse's back. Careful attention was paid to the positioning of the stimulus belt; measurements were taken to ensure that the first solenoid behind the head was located 12.0 cm behind the withers. A small mark made on the 1st day with a permanent marker on the horse's back designated the placement of the first solenoid.

After the stimulus belt was put on the horse, the horse was allowed to become accustomed to the belt for a few minutes. During this time the experimenters mounted the response panel in the stall's doorway and made the electrical connections. The horse was then positioned in front of the panel and tied with a 1.5-m lead rope that limited the horse's movement; the rope prevented excessive movements that might shift the position of the stimulus belt or stress the electrical connections.

During the 1st day, each horse was trained to press the response lever with its lips. This was accomplished using the method of successive approximations (Dougherty & Lewis, 1991, 1992; Ferster & Skinner, 1957). By first delivering small quantities of grain (approximately 60 mL) when the horse was near the lever, and then requiring closer approximations to the lip-press response, all horses were trained to press the lever. As soon as the horse acquired the lip-press response, it was given 60 additional deliveries of grain on a continuous reinforcement (CRF) schedule, under which every response was followed by a reinforcer. On the 2nd day, each horse received an additional 60 reinforcers on the CRF schedule.

For the next 6 days, the lip-press response was maintained on one of two variable-interval (VI) reinforcement schedules to ensure that horses would respond during the longer reinforcement schedules to be used later. It also allowed the horses to become accustomed to the stimulus belt's operation. During these sessions a stimulus (the training stimulus) remained on. The training stimulus was varied between horses: For Kay and No Sweat it was the stimulus nearest the head, and for Chris it was the one nearest the tail. These 6 days included 3 days each of two different schedules: VI 15 s and VI 30 s. On average, the time between reinforcers was equal to these two values, but individual intervals were sometimes shorter and sometimes longer. The intervals used in all schedules were generated using the Fleshler and Hoffman (1962) progressions (using 25 steps). The intervals were arranged in random order. Sessions were conducted daily and lasted until the horse had received 60 reinforcers.

For the next 10 days, training with the training stimulus was continued using a slightly different procedure: The reinforcement schedule was lengthened to VI 60 s and the training stimulus was turned off periodically. Stimulus-on periods alternated with stimulus-off periods: The training stimulus was turned on for 60 s and then was turned off for 10 s. Reinforcers were available only during the stimulus-on periods. The timing of an interval was stopped during a stimulus-off period and was then reactivated when the next stimulus-on period followed. The experimenters recorded the number of responses and stimulus-on periods to determine the rates of responding during these sessions.

Stimulus Generalization

Stimulus generalization testing followed the 10 days of VI 60-s schedule training. The procedure used here was similar to the one we used before (Dougherty & Lewis, 1991). A testing session consisted of seven testing blocks and seven refresher blocks. In a testing block, all seven tactile stimuli were presented in a predetermined (random) order for 60 s each, and each stimulus was separated by a 10-s stimulus-off period. No reinforcers were available within testing blocks. Between every testing block, a refresher block was given. In a refresher block, the training stimulus was presented for three 60-s periods (which alternated with 10-s stimulus-off periods); during a refresher block, six reinforcers were available on a VI 30-s schedule. A testing session was complete after the seven testing blocks and seven refresher blocks had been presented; the experiment was complete after all horses had received two testing sessions. To construct generalization gradients, the number of responses were recorded during each of the stimulus periods.

RESULTS

The preliminary training proceeded quickly; all horses became accustomed to the stimulus belt and learned the lip-press response. When the stimulus belt was first strapped to the horse's back, only a few efforts were made to shake or pull the stimulus belt off. Later, when the first tactile stimulus was turned on, the experimenters observed only a mild startle response. It took only a few minutes to accustom the horse to the tactile stimulus. As soon as the horse was tied in front of the response panel, in preparation for the training of the lip-press response, it explored it thoroughly. This made the training of the response easy; it took about 35 min to shape the behavior of each horse. A small number of grain deliveries were necessary to train the response: 18 for Chris, 23 for Kay, and 12 for No Sweat.

The number of responses were recorded during the last five sessions of VI 60-s schedule training, and from these we calculated mean

Table 1

Rates of responding (responses per minute) for each horse during the last five sessions of VI 60-s preliminary training.

	Session					
Subject	6	7	8	9	10	*M*
Chris	12.0	14.5	16.0	13.3	14.0	14.0
Kay	14.9	19.4	10.7	13.0	13.3	14.3
No Sweat	39.3	20.8	21.2	30.9	16.4	25.7

rates of responding for each horse. These means, which tended to be stable across sessions, appear in Table 1. Horses' overall mean responses per minute (across all five sessions) were 14.0 for Chris, 14.3 for Kay, and 25.7 for No Sweat.

In Figure 3, the results of the stimulus generalization testing for Chris, Kay, and No Sweat are shown. Each point in the gradient represents the total number of responses (across both days of testing) made by each horse to each of the stimuli presented during the testing blocks. The gradients were similar in shape and were independent of whether the training stimulus was located near the head (Kay and No Sweat) or near the tail (Chris). During generalization testing, the total number of responses emitted during both sessions for Chris, Kay, and No Sweat were 3,755, 2,580, and 4,275, respectively. The greatest number of responses were made in the presence of the training stimulus. The horse's tendency to respond to another stimulus depended on the position of the other stimulus: The farther away from the training stimulus, the fewer the responses.

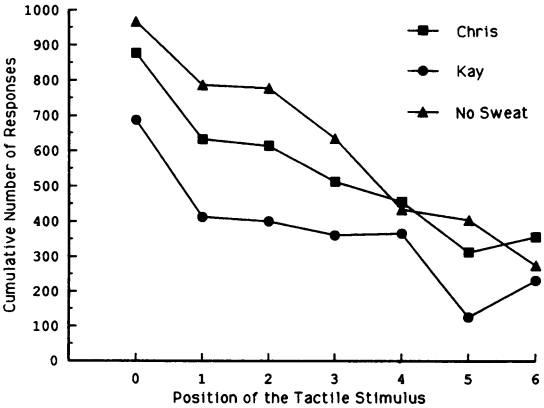

Fig. 3. Shown are the generalization gradients obtained from the 2 days of stimulus generalization testing. The stimulus labeled 0 was the training stimulus, and the other stimuli labeled 1 through 6 are the other novel test stimuli (the stimulus closest to the training stimulus is 1 and the stimulus farthest from the training stimulus is 6). For Kay and No Sweat, the training stimulus was the solenoid nearest the head, and for Chris it was the stimulus nearest the tail. During each day of testing, each of the seven stimuli were presented seven times (for 60 s), each in a different position in the testing blocks. The number of responses were summed for each of the seven stimuli across all presentations; the sums for each are represented on the graph as a single point.

DISCUSSION

In the present experiment, we found a tactile stimulus (a light tapping pressure delivered to the horse's back) to be an effective stimulus controlling a horse's operant response. Control was established by first training the horse to press a response lever with its lips and then maintaining this response on intermittent-reinforcement schedules. After these preliminary steps, horses were presented with all seven tactile stimuli in a testing procedure, and the number of responses were recorded in the presence of each. We found that the training stimulus controlled the most behavior: Horses emitted the highest number of lip-pressing responses in its presence. The six other test stimuli, all differing in their relative distance from the training stimulus, each controlled less behavior than the training stimulus. The effectiveness of a particular test stimulus depended on its position relative to the training stimulus: The closer the stimulus was to the training stimulus, the more effective was its control. These generalization gradients (Figure 3) demonstrate that the horses' behavior was differentially controlled by these stimuli regardless of the location of the training stimulus.

There were several important features of our testing procedure that may have contributed to the shape of our generalization gradients. First, the manner in which the tactile stimuli were delivered may have affected the shape of the gradients and may limit our interpretation of the data. The tactile stimuli, when operated, were accompanied by a very soft auditory clicking noise. This noise may have been discriminable on the basis of its location along the horse's back, and as a result may have led to a distinctive sound-location stimulus. Second, the manner in which the generalization testing was carried out may have contributed to the shape of the resultant generalization gradients. During the testing procedure a certain amount of interdimensional training was given in two ways: (a) Stimulus presentations within blocks of testing were alternated with 10-s stimulus-off periods and (b) during refresher blocks the training stimulus was presented and responses were reinforced. These aspects of the testing procedure provided an opportunity for interdimensional training to occur, and because some degree of discrimination training was provided during testing, the horses' gradients did sharpen as the testing sessions progressed. As a result, the gradients obtained are postdiscrimination gradients. Undoubtedly, some or all of these features of the experimental procedure contributed to the shape of the generalization gradients.

The consistency of the subjects' behavior, the strength of the stimulus control over the horses' responding, and the apparent usefulness of the conditioning procedures lead us to think about the applicability of the operant analysis to horse-training procedures in general. Horse training is an interesting area of application because it surely is the largest animal training enterprise in the world. The word dressage, a major category in horse competition, comes from the French word for training. A casual inspection of dozens of horse-training books reveals little awareness of the language and power of a conditioning analysis. These manuals often contain a long list of practices and concepts that have no justification in research evidence. Common among these is an emphasis on the rider communicating with the horse; another is an attempt to make the horse compliant with a rider's intentions.

There are several conditioning procedures relevant to attempts to train horses. First, horses are gradually adapted to novel stimuli. Because horses are flight-oriented animals and are strong (often capable of breaking physical restraints), all attempts at training are ineffective if the horse is not calm enough to receive stimuli. Afterwards, the horses are conditioned to respond to stimuli using aversive control procedures: Performance is the result of avoidance and escape conditioning under the control of discriminative stimuli. Usually the stimuli are tactile, but sometimes they are auditory. Complex performances involve large numbers of stimuli, and many times the behavior controlled by a stimulus differs when the stimulus is combined with another stimulus.

The primary nonaversive stimuli in horse training are tactile: the pressing of the rider's legs against the horse's sides, the shifting of the rider's weight forward and backward, and the slight pressure of lifting the reins leading to the horse's bit on one or both sides of the horse's mouth. The reinforcers used are primarily negative (e.g., spurs, whips, and bits). The horse's bit, probably the primary source of aversive stimulation, is carefully designed to allow the delivery of an aversive event to the horse in a sensitive spot using little effort by the rider. This is accomplished by a system of leather straps that hold the metal bit in the horse's mouth. By putting pressure on the reins attached to the bit, the rider brings the bit to bear on the horse's jaw bones. The bit rests on the horse's jaw bone and fits comfortably into spaces between the horse's teeth. These bones, being very sensitive, are easily stimulated when the rider puts tension on the reins attached to the bit. The horse's behavior is readily reinforced by escape and avoidance of these stimuli.

An understanding of the conditioning processes involved in training horses is lost because of two confusing factors. One is that the reins, through their attachment to the bit, are used to deliver both nonaversive and aversive stimuli. Another is that in the execution of a complex performance, the source of the causal variables is no longer present: It is bad form to whip a horse in the final contest. The nature of avoidance conditioning is that the aversive stimulus is not obvious to the observer and is not always obvious to the trainer.

It is difficult to see how the training of horses could not benefit from an understanding of the stimulus control of negatively reinforced behavior. Many of the large number of horses with behavioral problems, we are inclined to think, have problems because the training regimen failed to employ appropriate conditioning techniques or employed techniques that are at cross purposes. The tactile stimuli in the present experiment conformed exactly to our expectations based on a conditioning analysis.

Whether the analysis will be applied on a wide scale remains to be seen.

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